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BIOLOGY AND MORPHOLOGY OF THE MATURE LARVA OF *OXYETHIRA ARIZONA* ROSS (TRICHOPTERA: HYDROPTILIDAE)

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Abstract.—The biology and morphology of the fifth instar of *Oxyethira arizona* Ross are given. Larvae were taken from a cattail stand (*Typha* sp.) growing in a constructed wetland located in southern California. Adults were collected in pan traps placed at the edge and center of the cattail stand. Laboratory observations showed that larvae fed on individual cells within filaments of the green alga *Oedogonium* which grew epiphytically on submerged portions of the plants. Larvae used asymmetric mandibles for simultaneously grasping and piercing the cell walls to remove the liquid contents. Most (88.1%) of the adults taken were males, and 82.1% of males and all females were obtained at the periphery of the cattail stand. This is the first report of a hydroptilid larva feeding on *Oedogonium*, and is the first time *O. arizona* has been reported from California.

Key Words.—Insecta, microcaddisflies, *Oxyethira*, larvae, algae, *Oedogonium*, constructed wetlands.

The Hydroptilidae (Trichoptera), or microcaddisflies, are represented by 16 genera (Wiggins 1996a) and more than 200 species (Morse 1993) in North America; the number of described species known from this region continues to increase (e.g., Houp et al. 1998). Little is known about their biology despite their notable species richness, and most of our information is based on observations of species from other biogeographic regions (Nielsen 1948, Ito & Kawamura 1980, Wells 1985). The immature stages are known for only a small fraction of the described species (Wiggins 1990, 1996a).

Oxyethira Eaton is represented in North America by roughly 40 described species (Wiggins 1996b). Larvae are associated with lentic or slow-flowing lotic environments (Wiggins 1996a) and consume the contents of individual cells within filaments of green algae (Chlorophyta) (Nielsen 1948, Keiper et al. 1998). Larvae in the final stadium are easily distinguished from other North American hydroptilid genera by their long legs, relatively long antennae, and unique flask-shaped case (Wiggins 1996a).

Herein, we describe the final instar of *Oxyethira arizona* Ross, a species newly recorded for California, and give biological details. Previously, this species was recorded from Arizona only (Blickle 1979) and the larva was unknown.

MATERIALS AND METHODS

Final instars, pupae, and adults were obtained from the Prado Wetlands, a constructed wetlands near Corona (Riverside County, California). This 121.5 ha marsh receives water from the Santa Ana River to act as a biofilter for potential drinking water and to aid in flood control. The marsh is composed of 46 individual ponds interconnected by water control structures. Cattails (*Typha* sp.) and California bulrush (*Schoenoplectus californicus* [Meyer] Soják) became established within 1 yr of pond construction, and other plants such as buttercups (*Ranunculus*

flammula var. *ovalis* [Bigel.] and *R. aquaticus* var. *capillaceus* [Thuill.]), pennywort (*Hydrocotyle ranunculoides* L.), smart weeds (*Polygonum* sp.), and pond weeds (*Potamogeton* sp.) colonized the marsh shortly thereafter.

Yellow pan traps (33 × 28 × 14 cm Rubbermaid™ 11.5 quart dish basins) were placed biweekly in a *Typha* stand growing in approximately 1 m of water to collect adults. Each pan was filled with approximately 3 cm of water to which several drops of liquid detergent were added, and left for 24 h. Two traps were placed at the edge of the stand and were separated by 20 m. Two traps were placed within the stand 4–5 m from the periphery. The gender of each adult collected was determined, and specimens were preserved in 70% ethanol.

Larvae and pupae were taken from the submerged portions of cattail plants, woody debris, and dead cattail leaves floating near the water surface; these substrates had visible growths of the filamentous green alga *Oedogonium* sp. (Chlorophyta). All living specimens were placed in jars of marsh water, the jars put in a cooler with ice, and transported back to the laboratory for study.

A representative number of larvae and pupae were fixed in KAA solution, and perserved in 70% ethanol following the methods of Wiggins (1996a). The remainder were placed in small petri dishes with marsh water and sections of dead cattail with epiphytic *Oedogonium*. To observe larval feeding habits, living larvae were observed at 6–50 × with a Wild M5 dissecting microscope. Preserved specimens of mature larvae ($n = 4$) were described, and measurements obtained with an ocular micrometer on the Wild microscope.

Results and Discussion

Morphology.—Living larvae and their cases appeared very similar to those illustrated by Wiggins (1996a), except sclerites pale. Non-sclerotized areas of body with many small green patches of pigmentation; this coloration was lost when placed in KAA solution or ethanol. Abdominal segments IX–X were curved ventrad in living and preserved larvae. Case constructed from silken secretions only, narrow and flask-shaped, tapering to constricted opening at anterior end, posterior edge of valves broad, flat, and compressed laterally, similar to case described by Wiggins (1996a) (Fig. 1); pupal cocoon not separate from the silken wall of the external case.

Total length, 2.307 ± 0.950 mm; head length, 0.231 ± 0.004 mm, width 0.196 ± 0.003 mm. Head pale, somewhat darker than abdomen. Two rows of 3–4 brown muscle scars slightly behind level of eye spots, 6 brown muscle scars staggered along posterior margin of head capsule. Setation as in Fig. 2. Antennae situated near antero-lateral margins of head, each with basal seta approximately half as long as antenna. Mandibles yellowish, asymmetrical, right pointed with subapical cusp, left serrated on inner margin and terminating with two teeth (incisor cusps), two setae on posteriolateral corner (Fig. 3).

Thorax concolorous with head, 0.423 ± 0.004 mm long. Three pairs of muscle scars near poterior margin of pronotum, variable number of muscle scars scattered laterally. Prosternal sclerites concolorous with head; lateral two sclerites narrow, central sclerite relatively large and rectangular; meso- and metanotal sclerites lacking muscle scars, posterolateral corners with black spot; meso- and metasternal sclerites positioned posteriorly, narrow, and black. Front leg (from base of coxa) 0.456 ± 0.009 mm long, tarsal claw long, fore tibiae each with medio-distal projection (Fig. 4), middle leg 1.006 ± 0.048 mm long, hind leg 1.053 ± 0.156 mm long; leg length ratio 1.00:2.21:2.31.

Abdomen 1.753 ± 0.040 mm long, milky white except for pigmented areas described above, greatly distended in mature larvae. Primary setae pale and short. Sclerites of segments 9 and 10 concolorous with head. Claw of anal proleg somewhat darker than other sclerites, approximately 0.020 mm long in lateral view.

Diagnosis.—Ross (1944) stated that there are no distinguishing characters to separate larvae of *Oxyethra* in Illinois. Conversely, Back (1983) provided a key

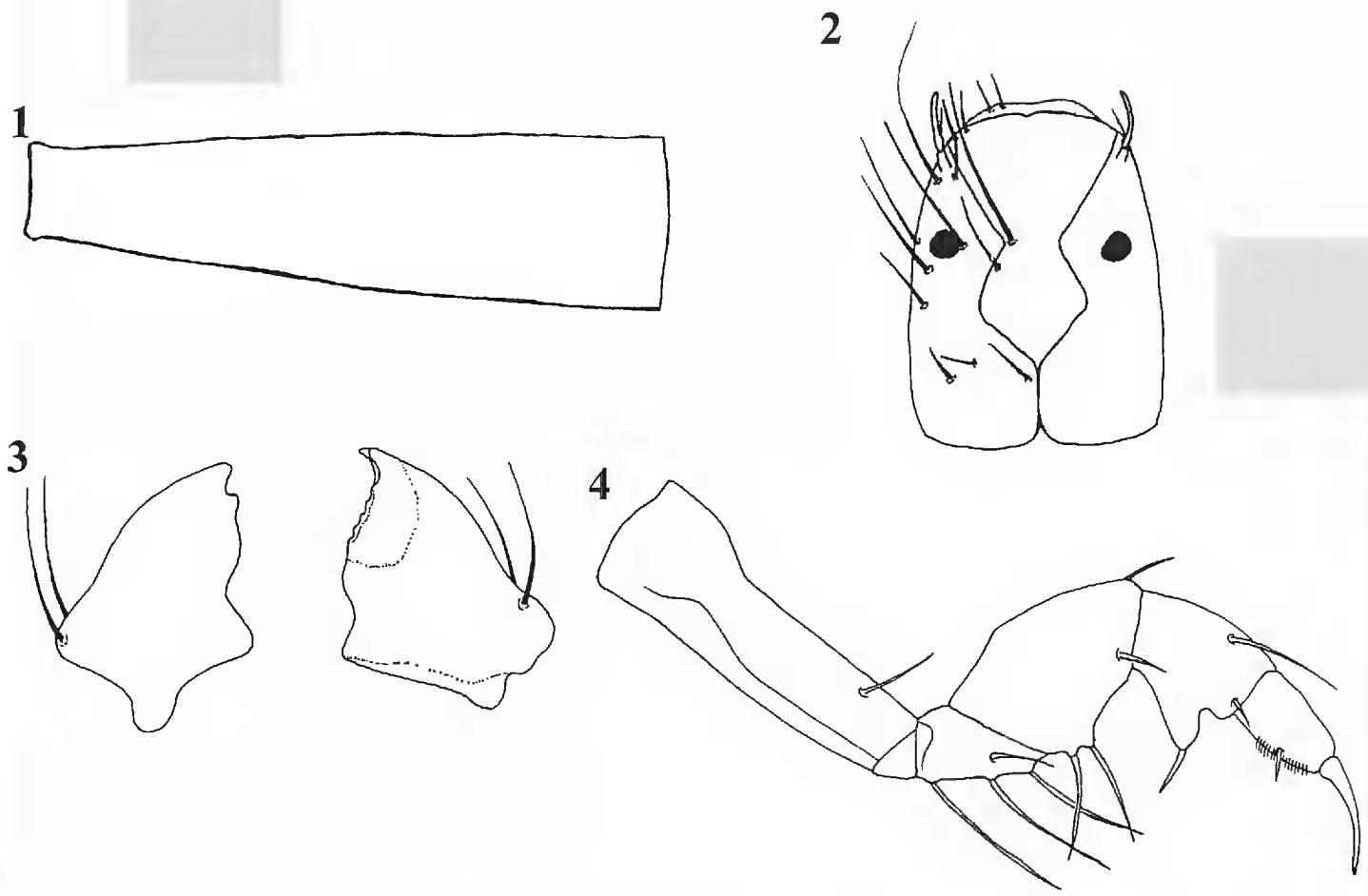

Figure 1. Profile of portable case, lateral view.
Figure 2. Head capsule showing primary setae on left side, dorsal view.
Figure 3. Mandibles, ventral view.
Figure 4. Right foreleg, lateral view.

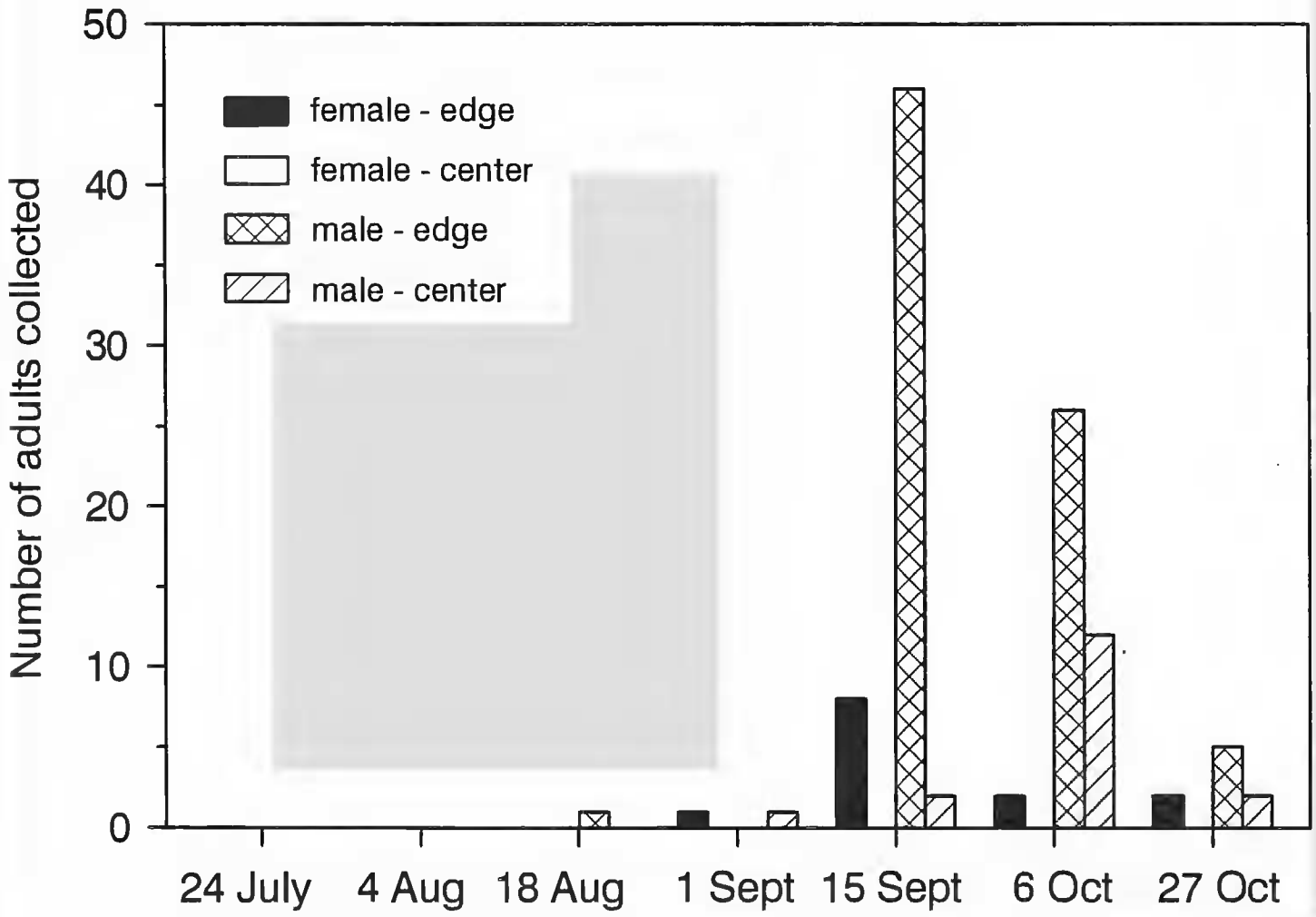

Figure 5. Total numbers of adult males and females taken in pan traps placed at the edge and center of a *Typha* stand during 1998.

to separate *O. leonensis* Kelly and *O. dualis* Morton, indicating that leg length ratio is important to identifying larvae to species. *Oxyethira arizona* has middle and hind legs twice as long as front legs, whereas *O. leonensis* and *O. dualis* have middle and hind legs four and three times as long as front legs, respectively. Our work suggests that mandible morphology is also important. The mandibles of Hydroptilidae are normally asymmetrical (e.g., Nielsen 1948, Huryn 1985, Wells 1985, Keiper & Foote 1998, Keiper & Walton, in press), but no asymmetry was described for those of *O. leonensis* (Back 1983). Furthermore, number of setae on the posterolateral corners of the mandibles are often distinct among species of the same genus (J. B. Keiper, unpublished data), as is the case with *O. arizona* and *O. leonensis*.

Biology—Larvae moved among masses of *Oedogonium*, pulling themselves along filaments with their forelegs. The middle and hind legs of larvae appeared to balance or steady larvae, but were not used to grasp filaments. One larva was observed on several occasions to move through a mass of algae, and halted when it reached the water surface. When it continued to move, its long middle and hind legs often became trapped in the surface tension of the water. It appeared to struggle when its legs were trapped, and was able to free its legs only by withdrawing completely into its case. Eventually, it reversed position within its case, forced its head and thoracic segments through the tightly appressed but flexible posterior end of the silken case, and moved down the algal mass toward the dish bottom. After clearing the water surface, the larva reversed position within its case again so that its head and thoracic segments protruded from the anterior opening.

Larvae fed on individual cells within filaments of *Oedogonium*. During feeding bouts, larvae grasped single filaments of *Oedogonium* with their forelegs, and passed them up past their mouthparts. The mandibles executed 2–3 adductions; the first one or two bites pierced the cell wall with the pointed right mandible while the left one maintained a stable hold on the filament with its serrated inner edge; the last bite pulled the filament tightly to their mouths. The larvae placed their mouths over the break in the cell wall, and removed the cellular protoplast with an apparent sucking action. Larvae then executed another feeding bout on the next cell in the filament. Larvae required approximately 2–3 sec to consume a cell, and up to 30 cells were attacked in rapid, machine-like succession. A bolus of protoplast formed by up to five cells accumulated in the foregut before the larva swallowed it, adding the bolus to the dark green mass within its gut. Several filaments of *Oedogonium* damaged by larval feeding were observed at 100×, and a single puncture created by the tip of the right mandible was present on each of the emptied cells. Although a biofilm of diatoms, unicellular green algae, and other organisms grew on the dead sections of cattails and algal filaments given to the larvae, they never attempted to scrape the biofilm from these substrates.

Larvae attached their cases to living and dead cattail stems using three silken guy lines; one was secured to the anterior end of the case, whereas the other two were positioned posterolaterally. The anterior opening was closed with a plug of silk, and the posterior flaps were sealed with silk as well. Pupating larvae were observed in the laboratory to weave their heads laterally and vertically while spinning a silken coccoon. Prepupae were positioned sideways in their cases, but all pupae observed were postitioned so their ventral surfaces laid against the valve

Table 1. Preliminary list of aquatic macroinvertebrates collected from the Prado Constructed Wetlands.

Taxon	Functional feeding group
INSECTA	
Ephemeroptera	
Baetidae	
Callibaetis	collector/gatherer
Odonata	
Coenagrionidae	
Enallagma	predator
Ischnura	predator
Aeshnidae	
Aeshna	predator
Anax	predator
Libellulidae	
Pachydiplax	predator
Sympetrum	predator
Tramea	predator
Hemiptera	
Belostomatidae	
Belostoma	predator
Corixidae	
Corisella	detritivore/scavenger (generalist)
Hesperocorixa	detritivore/scavenger (generalist)
Notonectidae	
Buenoa	predator
Notonecta	predator
Coleoptera	
Dytiscidae	
Cybister	predator
Laccophilus	predator
Thermonectus	predator
Hydrophilidae	
Berosus	predator (larva); detritivore/herbivore (adult)
Hydrophilus	predator (larva); detritivore/herbivore (adult)
Tropisternus	predator (larva); detritivore/herbivore (adult)
Trichoptera	
Hydroptilidae	
Hydroptila ajax	piercer/herbivore (*Cladophora*)
Oxyethira arizona	piercer/herbivore (*Oedogonium*)
Diptera	
Chironomidae	collector/gatherer
Culicidae	
Culex	filter feeder
Culiseta	filter feeder
Anopheles	filter feeder
Ephydridae	
Brachydeutera	collector/gatherer
Hydrellia	herbivore (*Lemna*)
Sciomyzidae	
Dictya	predator (Gastropoda)
Pherbellia	predator (Gastropoda)
Sepedon	predator (Gastropoda)
Syrphidae	collector/gatherer

Table 1. Continued.

Taxon	Functional feeding group
OTHER	
Platyhelminthes	
Annelida	
Hirudinea	
Gastropoda	
Acari	
Decapoda	

appressed to the substrate. Cases were located on living cattails approximately 0.3 meters above the sediment, and 0.2 meters below the water surface; there was no observable pattern to their distribution or orientation on the plants. On one plant examined, pupal cases were found between two closely-positioned cattail leaves. No algae grew here, but this location probably provided a superior pupation site for defense against predators and abiotic stress.

Wiggins & Wichard (1989) discussed the phylogeny of pupation in the Trichoptera and stated that microcaddisfly larvae usually spin cocoons discrete from the silken case prior to pupation. *Oxyethira arizona* is an exception to this generalization as larvae added a silken layer directly to the case interior. Examination of the pupal cases of other *Oxyethira* spp. and those of all hydroptilid genera should be performed to clarify microcaddisfly pupal cocoon morphology and its use in determining the higher phylogeny of Trichoptera.

Adults were taken first on 18 Aug 1998, total numbers peaked on 15 Sep 1998, and the numbers declined precipitously as the autumn months progressed (Fig. 5); the total catch comprised 88.1% males and 11.9% females. Most males (82.1%) and all females were collected in the traps placed at the edge of the stand. The high proportion of adults collected at the edge may represent a biological phenomenon such as oviposition preferences or mating behavior. The skewed sex ratio (over 7:1) may be a result of sampling technique (i.e., perhaps males alight on the water surface to rest more frequently than females), but laboratory rearings of 18 field-collected pupae produced 15 males and 3 females (5:1 ratio). This demonstrates that the population of *O. arizona* studied produces many more males than females.

Constructed wetlands are an increasingly common occurrence in the arid southwestern United States (Walton & Workman 1998), and invertebrate animals with the ability to colonize novel habitats are an important feature for their successful establishment as ecological communities. The *O. arizona* population of the Prado Constructed Wetlands appeared to be well established as many pupal cases were observed in several localities within the marsh. We provide a preliminary list of aquatic invertebrates taken from the Prado Constructed Wetlands because they represent important colonizers (Table 1). The only other microcaddisfly taken during this study was *Hydroptila ajax* Ross, a specialist consumer of *Cladophora* (J. B. Keiper, unpublished data); only a few larvae and adults were collected suggesting that this species is either a recent colonizer or not well suited for the marsh environment. The two hydroptilid species are unique components of the invertebrate community because of their apparently specialized feeding habits.

Table 2. Known food sources consumed by larval Hydroptilidae.

	Chlorophta					*Rhodophyta*					
	Cladophora	*Oedogonium*	Oedogoniales	*Spirogyra*	*Zygnema*	*Batracho-spermum*	*Lemanea*	liverwort	diatoms	detritus	References
Ptilocolepinae											
Palaeagapetus								x			Flint 1962; Ito, 1997, 1998
Ptilocolepus								x			Ito 1993
Hydroptilini											
Agraylea	x								x		Nielsen 1948
Dibusa							x				Resh and Houp 1986
Hydroptila	x		x		x				x		Nielsen 1948, Ito & Kawamura 1980, Huryn 1985, Wells 1985, Keiper et al. 1998, Keiper and Foote 1999
Maydenoptila						x					Wells 1985
Ochrotrichia	x								x		Keiper & Foote 1998, Keiper & Walton, in press
Oxyethira		x		x	x						Nielsen 1948, Back 1983, Keiper et al. 1998
Stactobiini											
Stactobiella										x	Wiggins 1996b
Leucotrichiini											
Leucotrichia									x		McAuliffe 1982
Zumatrichia									x		Wiggins 1996a, b
Orthotrichiini											
Ithytrichia									x		Wiggins 1996a, b
Orthotrichia	x								x		Nielsen 1948, Wells 1985, J. B. Keiper, unpublished data
Neotrichiini											
Neotrichia									x		Wiggins 1996b
Mayatrichia									x		Wiggins 1996a, b

Although a variety of functional feeding groups (Merritt & Cummins 1996) are represented, the other taxa encountered appear to be predators or otherwise generalized trophically, with the exception of an undetermined species of *Hydrellia* (Diptera: Ephydridae) which appears to be a specialist consumer of duckweed (Lemnaceae: *Lemna minor* L.) (J. B. Keiper, unpublished data).

Remarks.—This is the first report of hydroptilid larvae from North America consuming *Oedogonium.* Ito & Kawamura (1980) noted that *H. itoi* Kobayashi from Japan fed on Oedogoniales and diatoms, but no further descriptions of the food sources were given. Our report confirms that *Oedogonium* is consumed by Hydroptilidae (Table 2). Further investigations into the general biology of this relatively neglected group will probably describe additional food items, such as other genera of filamentous green algae, consumed by this speciose group. These data will facilitate a better understanding of the adaptive radiations that have taken place among the species of *Oxyethira* and the Hydroptilidae in general.

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LITERATURE CITED

Back, R. C. 1983. Larva and pupa of *Oxyethira leonensis* (Trichoptera: Hydroptilidae). Fla. Entomol., 66: 389–392.

Blickle, R. L. 1979. Hydroptilidae (Trichoptera) of America North of Mexico. New Hampshire Agric. Exp. Stat. Bull., 509: 1–97.

Flint, O. S. 1962. The immature stages of *Paleagapetus celsus* Ross (Trichoptera: Hydroptilidae). Bull. Brooklyn Entomol. Soc., 57: 40–44.

Houp R. E., K. H. Houp & S. C. Harris. 1998. Two new species of microcaddisflies (Trichoptera: Hydroptilidae) from Kentucky. Entomol. News, 109: 99–102.

Huryn, A. D. 1985. A new species of *Hydroptila* (Trichoptera: Hydroptilidae) from North Carolina. Proc. Entomol. Soc. Wash., 87: 444–447.

Ito, T. 1993. Biological notes and description of little-known stages of *Ptilocolepus granulatus* (Pictet) (Trichoptera, Hydroptilidae). pp. 177–181. *In* Otto, C. (ed.). Proceedings of the 7th International Symposium on Trichoptera. Backhuys Pub., Leiden.

Ito, T. 1997. Oviposition preference and behavior of hatched larvae of an oligophagous caddisfly, *Palaeagapetus ovatus* (Hydroptilidae: Ptilocolepinae). pp. 177–181. *In* Holzenthal, R. W. & O. S. Flint (eds.). Proceedings of the 8th International Symposium on Trichoptera. Ohio Biological Survey, Columbus.

Ito, T. 1998. The biology of the primitive, distinctly crenophilic caddisflies, Ptilocolepinae (Trichoptera: Hydroptilidae). A review. pp. 85–94. *In* Botosaneanu, L. (ed.). Studies in crenobiology—the biology of springs and springbrooks. Backhuys Publishers, Leiden.

Ito, T. & H. Kawamura. 1980. Morphology and biology of the immature stages of *Hydroptila itoi* Kobayashi (Trichoptera, Hydroptilidae). Aq. Insects, 2: 113–122.

Keiper, J. B., D. A. Casamatta & B. A. Foote. 1998. Use of algal monocultures by larvae of *Hydroptila waubesiana* and *Oxyethira pallida* (Trichoptera: Hydroptilidae). Hydrobiologia, 380: 87–91.

Keiper, J. B. & B. A. Foote. 1998. Notes on the biology of *Ochrotrichia xena* Ross (Trichoptera: Hydroptilidae), a species newly recorded for Ohio. Proc. Entomol. Soc. Wash., 100: 594–595.

Keiper, J. B. & B. A. Foote. 1999. Biology and immature stages of two species of *Hydroptila* Dalman

(Trichoptera: Hydroptilidae) which consume *Cladophora* (Chloraphyta). Proc. Entomol. Soc. Wash., 101: 514–521.

Keiper, J. B. & W. E. Walton. (in press). Biology and immature stages of *Ochrotrichia quadrispina* (Trichoptera: Hydroptilidae), a spring-inhabiting scraper. Proc. Entomol. Soc. Wash., 102.

McAuliffe, J. R. 1982. Behavior and life history of *Leucotrichia pictipes* (Banks) (Trichoptera: Hydroptilidae) with special emphasis on case reoccupancy. Can. J. Zool., 60: 1557–1561.

Merritt, R. W. & K. W. Cummins. 1996. An introduction to the aquatic insects of North America (2nd ed.). Kendall Hunt Publishing Co., Dubuque.

Morse, J. C. 1993. A checklist of the Trichoptera of North America, including Greenland and Mexico. Trans. Am. Entomol. Soc., 119: 47–93.

Nielsen, A. 1948. Postembryonic development and biology of the Hydroptilidae. Kgl. Danske Vidensk. Selsk. Biol. Skr., 5: 1–200.

Resh, V. H. & R. E. Houp. 1986. Life history of the caddisfly *Dibusa angata* and its association with the red alga *Lemanea australis*. J. N. Am. Benthol. Soc., 5: 28–40.

Walton, W. E. & P. D. Workman. 1998. Effect of marsh design on the abundance of mosquitoes in experimental constructed wetlands in southern California. J. Am. Mosquito Control Assoc., 14: 95–107.

Wells, A. 1985. Larvae and pupae of Australian Hydroptilidae, (Trichoptera), with observations on general biology and relationships. Aust. J. Zool. Supplement, 113: 1–69.

Wiggins, G. B. 1990. Systematics of North American Trichoptera: present status and future prospect. pp. 203–210. *In* Kosztarab, M. & C. W. Schaefer (eds.). Systematics of the North American insects and arachnids: status and needs. Virginia Agricultural Experiment Station Information Series 90-1. Virginia Polytechnic Institute and University, Blacksburg.

Wiggins, G. B. 1996a. Larvae of the North American caddisfly genera (Trichoptera) (2nd ed.). University of Toronto Press, Buffalo.

Wiggins, G. B. 1996b. Trichoptera families. pp. 309–349. *In* Merritt, R. W. & K. W. Cummins (eds.). Aquatic insects of North America (3rd ed.). Kendall/Hunt Publishing Co., Dubuque.

Wiggins, G. B. & W. Wichard. 1989. Phylogeny of pupation in Trichoptera, with proposals on the origin and higher classification of the order. J. N. Am. Benthol. Soc., 8: 260–276.

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